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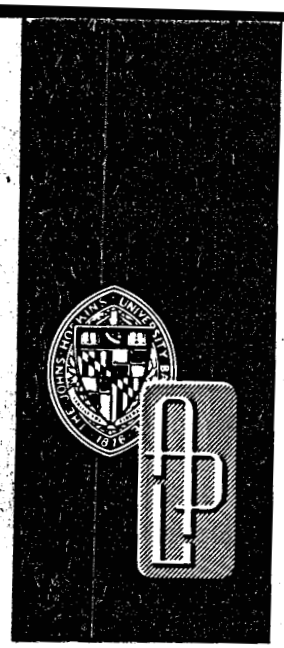

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Geothermal Energy Market Study on the Atlantic Coastal Plain

A REVIEW OF RECENT ENERGY PRICE PROJECTIONS FOR TRADITIONAL SPACE HEATING FUEL 1985–2000

Richard Weissbrod and William Barron
The Center for Metropolitan Planning and Research
The Johns Hopkins University, Baltimore, Maryland 21218

This work was supported by The Department of Energy under Interagency agreements No. EX-76-A-36-1008 and DE-AIo1-79-ET27025

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The GEMS Report Series is planned to be issued in the following parts:

GEMS-001	Executive Summary
GEMS-002	Definition of Markets for Geothermal Energy in Northern Atlantic Coastal Plain
GEMS-003	System Design Concepts and Geothermal Energy Economics
GEMS-004	Geothermal Energy Costs on the Northern Atlantic Coastal Plain
GEMS-005	A Review of Recent Energy Price Projections for Traditional Space Heating Fuel 1985-2000
GEMS-006	Geothermal Energy Market Penetration on the Atlantic Coastal Plain

ABSTRACT

In order to develop an initial estimate of the potential competitiveness of low temperature (45° C to 100° C) geothermal resources on the Eastern Coastal Plain, the Center for Metropolitan Planning and Research of The Johns Hopkins University reviewed and compared available energy price projections. Series of projections covering the post-1985 period have been made by the Energy Information Administration, Brookhaven National Laboratory, and by private research firms. Since low temperature geothermal energy will compete primarily for the space and process heating markets currently held by petroleum, natural gas, and electricity, projected trends in the real prices for these fuels were examined. The spread in the current and in projected future prices for these fuels, which often serve identical end uses, underscores the influence of specific attributes of each type of fuel, such as cleanliness, security of supply, and governmental regulation. Geothermal energy possesses several important attributes in common with electricity (e.g., ease of maintenance and perceived security of supply), and thus the price of electric space heating is likely to be an upper bound on a competitive price for geothermal energy. Competitiveness would, of course, be increased if geothermal heat could be delivered for prices closer to those for oil and natural gas. The projections reviewed suggest that oil and gas prices will rise significantly in real terms over the next few decades, while electricity prices are projected to be more stable. Electricity prices will, however, remain above those for the other two fuels. The significance of this work rests on the fact that, in market economies, prices provide the fundamental signals needed for efficient resource allocation. Although market prices often fail to fully account for factors such as environmental impacts and long-term scarcity value, they nevertheless embody a considerable amount of information and are the primary guideposts for suppliers and consumers.

PREFACE

Research for this paper was conducted by the Center for Metropolitan Planning and Research (the Metro Center) under subcontract to the Applied Physics Laboratory of The Johns Hopkins University (APL/JHU) as part of the Geothermal Energy Market Study (GEMS) which was sponsored by the Division of Geothermal Energy of the Department of Energy (DOE/DGE)

The non-electric or direct use of geothermal energy necessarily involves transmission of hot water to user sites (residential, commercial, or industrial) through district heating systems. The demand for geothermal energy will normally depend on the delivery price, and how that price compares with prices for traditional space heating fuels, such as oil, natural gas, coal, and electricity. As an input to such an analysis, this paper reviews and compares a series of recent energy price projections for the traditional fuels.

However, in addition to providing a perspective on the prices which potential users may be willing to pay for geothermal energy, these projections are important in themselves. If the level of real price increases for the traditional fuels is within the range suggested by these models, significant adjustments will be required in most areas of the economy, and the dislocations caused by such changes can become a major public policy issue in the next two decades.

The substance of the present report will be incorporated in a final APL/JHU report on the market potential for moderate temperature geothermal energy in these regions and on the projected displacement of conventional fuel by geothermal for space heating and selected industrial processes.

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SUMMARY

This report reviews retail energy price projections made by the Energy Information Administration (June 1978), by Brookhaven National Laboratory (July 1978), and by Foster Associates (April 1977). Projections of "long-term marginal costs" for various fuels made by Stanford Research International (September 1977) are considered separately. Each of these organizations made at least two sets of projections based on different economic, resource, and policy assumptions. It should be emphasized that the prices cited here are more accurately characterized as projections based on each model's representation of the energy economy and best guesses about exogenous influences, rather than as forecasts of expected price levels. All prices cited in this report are in 1978 dollar values. Thus, these are "real" prices in the sense that the effects of the general rate of inflation have been eliminated from both figures given for 1975 price levels and those projected for future years.

In current dollar values, distillate fuel oil prices are generally projected to rise 40% to 70% above 1975 levels by 1990. Under Brookhaven's "worst case" scenario, this rise is well over 200%. Starting from a much lower 1975 base price, natural gas prices are projected to approach those for distillate on an equivalent BTU basis. By 1990, real natural gas prices may well be more than double 1975 levels. Electricity prices are projected to rise much more slowly than prices for other fuels and may decline sometime after 1985, but are likely to remain about twice as expensive as distillate or natural gas.

Any comparison of the actual price competitiveness of a specific fuel must, however, account for differences in the amount of heat each type of heating

system delivers to the building for each BTU of energy input. Efficiency is affected by a number of factors including system design and maintenance practices. Thus, there can be considerable variation within systems of the same type. The efficiency ratings given below are taken from FEA's Energy Interrelationships (FEA/B-77/166, June 1977), and are estimates of average overall efficiency for each type of heating system, i.e., the portion of energy consumed by the system which is delivered to the building as heat. Electric heating is generally very efficient. While some estimates use 100 percent, FEA's study uses 90 percent. Oil and natural gas systems are generally less efficient, being rated on the average at 60 percent and 70 percent respectively in the FEA study. Warm water geothermal systems, like electricity, are very efficient in terms of usable energy for energy delivered to the door. For illustrative purposes, an efficiency of 90 percent is assumed here. (Again, like electricity, most of the system inefficiencies for geothermal occur prior to delivery to the user.)

Electricity for space heating is still more expensive (and is projected to remain so) than space heating by oil and natural gas. It has made market penetration, however, on the basis of premium attributes such as perceived security of supply, cleanliness, and ease of maintenance. Geothermal should be able to capture some of these premium attributes. Thus, while market penetration by geothermal would be accelerated if it could be sold at prices competitive with oil and gas, the price of electric space heating is probably the effective upper limit.

Taking one set of 1990 price projections for electricity of 1547¢/MM BTU (in 1978 dollars), 489 for distillate fuel oil, and 416 for natural gas, and modifying for the efficiencies cited above, the price ceiling for geothermal energy would be about 1550¢/MM BTU. If it could be sold for under about 735, it would be price competitive with distillate. A price of 540 would be competitive with natural gas prices under this projection.

Regionally, the Northeastern portion of the country pays higher than average prices for natural gas and electricity and about average prices for petroleum. The South pays about average prices for electricity; lower than average prices for natural gas; and above average prices for petroleum. Although the Atlantic Coastal areas of interest to the low-grade geothermal project fall into different regional categories under each of the models considered, certain patterns hold which are useful in identifying specific price conditions in these areas. These price differentials are generally projected to hold throughout the forecast period. In most cases, as one moves south along the coast, each set of projections shows electricity and natural gas prices being lower and distillate prices being higher than in the more northerly areas.

INTRODUCTION

Since energy is such a vital component in the U.S. economy and way of life, the present and future cost and availability of energy are of special interest to us all. This concern has led to the search for non-traditional forms of energy to satisfy some of the national needs. These non-traditional sources of energy, such as warm water geothermal energy, must be evaluated against traditional and other non-traditional forms; in particular, they must be price competitive with the traditional forms. Since there are many reputable groups supplying price forecasts for traditional forms of energy, we have sampled some of these, and present them as the basis for evaluating non-traditional forms.

Widespread concern over energy prices developed out of the Arab Oil Embargo of 1973-74 and the coincident large jump in world prices for exported oil. Since 1974, consumers have been faced with steadily rising dollar outlays for energy. However, after the effects of the general rate of inflation have been eliminated, energy prices since 1975 have been rising only moderately, and, in some cases, have actually fallen for a time. In nominal dollars, crude oil prices rose from $7.67 per barrel (domestic average) to $8.57 in 1977. In real (1978) dollars, however, the price rose from $9.04 to only $9.08. Average monthly electric bills rose from $17.93 to $20.86 between 1975 and 1977 (in nominal dollars), while the price rise in constant 1978 dollars was from $21.12 to $22.11. Residential heating oil prices corrected for inflation fell from 1974 to 1975, and remained almost constant from 1975 to 1976, at just under 44¢/gallon, in 1978 dollars. However, they rose to 48.5¢ in 1977 (again in 1978 dollar values). Price rises for natural gas have been much steeper, even in constant dollar values, rising from 201.2¢/thousand cf in 1975 to 221.3 in 1977 (values in 1978 dollars).

These relatively moderate price rises are partially a result of governmental regulation and short-term market conditions. The future long-term trend for

energy prices, even after correction for inflation, appears very likely to be one of frequent and significant increases.

The energy price projections reviewed in this paper are based on the assumption that the declining resource base for traditional sources of oil and gas, and the desire of producers to capture scarcity rents, will cause continuing upward pressure on real prices, at least through the end of this century. It is projected that U.S. crude oil and natural gas production, under the most favorable conditions, will increase only moderately until sometime in the 1990's.[1] Beyond 1990, such production levels will be difficult to maintain. Worldwide oil production is expected to peak sometime in the 1990's.[2]

Eventually, average energy prices will be determined by the marginal (i.e., replacement) cost of production from coal, oil shale, and solar energy (which includes such sources as wind and biomass). Since the resource base for these resources is large or renewable, energy from such sources should be relatively stable in price. Unlike oil and gas, where current price is being increasingly determined by scarcity value and market conditions, the major uncertainties with the alternative sources of energy are their production costs under greatly expanded output levels. An interesting feature of this situation is that, in some respects, long-term energy prices appear to be more certain than near-term prices, which are greatly influenced by the decisions of producing nations regarding the rate of extraction of their exhaustible resources and the decisions of consuming nations regarding the speed of a transition to alternative sources of energy. Eventually, the prices for petroleum and natural gas will rise to at least the ceilings imposed by the production costs of the alternatives. One of the principal uncertainties is the time required to reach these ceilings.

Within the next two decades, major adjustments will be required in energy consumption patterns around the world. The role that government will play will be

crucial. On the one hand, there is concern that price deregulation only delays needed adjustment in supply and demand conditions, and that unnecessarily severe dislocations will occur when adjustments are made in a crisis environment. On the other hand, energy is a basic commodity, and increases in price bring hardship to many persons and help fuel inflation throughout the economy.

The price projections analyzed in this paper are, for the most part, products of large-scale econometric models, and thus, there are some caveats which must be mentioned. Any model is an abridgement of the actual situation, which is likely to be influenced by subtle and changing relationships and by factors, such as governmental policy, which are reevaluated and redirected over the course of decades. The prices cited in this report are projections based on each model's representation of important economic relationships, and are not forecasts of what future prices are necessarily expected to be. Even though these are large models capable of including varying economic conditions, resource discovery rates, and governmental policy, the results are still determined by the models' stylized representation of the real world. The value of these models lies in their ability to methodically work through a large number of detailed relationships, the implications of potential changes in energy supply and demand conditions. The models are not necessarily good predictors of the future, but they can be very useful in assessing the likely impacts of present and expected trends on specific areas of the economy.

The model scenarios considered in this report range from the Energy Information Administration's Projection Series D, which assumes constant real world prices, low demand, and relatively high energy supply; to Brookhaven National Laboratory's High Price III scenario, a "worst case" situation involving very high oil prices (up to $60 per barrel, based on the possibility that synthetic crude oil from coal and oil shale could be two or three times as expensive to produce as earlier estimates). Conditions reflected in Series D could possibly hold for a short time,

but it seems unlikely that incentives to increase supply and reduce demand would occur simultaneously. While the consequences of Brookhaven's High Price III scenarios are frightening, unless the price rise were very rapid, alternative sources of energy would come on line as quickly as they could be developed, and consumers could make the switch. Thus, the impacts of the higher oil prices would be lessened, at least for those sectors where alternative sources of energy exist. Again, it should be emphasized that, because these models cannot anticipate all possible responses to changing conditions, the estimates of future price levels are those that probably would result if the economy were relatively inflexible.

The purpose of this report is to outline current energy price projections through the end of this century. The economic viability of geothermal resources, as that of any new technology, will depend largely on its ability to match or undercut the prices of traditional sources of energy. Warm water geothermal is not widely used today because there are very few situations in which it competes in price with other sources of energy. It may, however, be competitive with prices for traditional fuels within a relatively few years. In addition to price competitiveness, certain premium attributes, such as perceived security of supply and low user maintenance requirements, may permit the sale of geothermal energy at prices somewhat above those for competing fuels. Although electric space heating is considerably more expensive than other types of heating on cost of purchased BTU basis, correction for average system efficiency reduces this difference from nearly 3 to close to 2 times as expensive. A study by N.B. Guyol for FEA (Energy Interrelationships, FEA/B-77/166, June 1977) estimated average heating system efficiencies at 90 percent for electricity, 70 percent for natural gas, and 60 percent for distillate fuel oil. While there can be considerable variation in efficiencies of systems of the same type (due to maintenance practices, levels of insulation, and other factors), the efficiencies

cited above are useful for gross adjustments for the amount of energy actually delivered to the building by each type of system for each BTU of energy input. Taking Brookhaven National Laboratory's basecase projections for 1990, the effective prices to the consumer for usable heat energy in the building (i.e., using Guyol's efficiencies), in ¢/MM BTU in 1978 dollars, are 1719 for electric space heating, 815 for oil, and 594 for natural gas.

While electricity prices are still projected to be above those for oil and natural gas in 1990, electricity has premium attributes such as perceived security of supply, cleanliness, and low maintenance, which have permitted it to make significant market penetration (SRI assumes a market premium of 260¢/MM BTU in 1978 dollars for electricity, compared to natural gas, for space heating). Geothermal energy may be marketable at prices above those for oil and gas, if it has efficiency and premium attributes similar to those for electricity. Thus, the price of electricity may be considered a minimum threshold price with which new sources of energy must compare successfully.

Section I of this report sets out the national average energy price projections. Section II considers the regionalized price projections. Although the national and regional prices are important for evaluating the attractiveness of geothermal energy, general trends in resource development are also important. For example, if synthetic crude oil production is delayed past the time predicted for the peaking of world oil production, shortages may occur which may place "security of supply" premiums on sources such as geothermal. Section III compares the resource development and other assumptions of the models.

I. NATIONAL ENERGY PRICE PROJECTIONS

Projections of retail energy prices were obtained from the Energy Information Administration's Annual Report to Congress (June 1978),[3] from a Brookhaven National Laboratory memorandum and by telephone (July 1978),[4] and from a report by Foster Associates (March 1977)[5] conducted for the Electric Power Research Institute (EPRI). EPRI also funded a study by Stanford Research International (SRI)[6] on long-term marginal prices for various fuels. Because marginal prices are not directly comparable to retail prices, SRI's projections are considered separately. Each of these organizations made two or more sets of price projections under varying assumptions regarding resource development, economic conditions, and governmental policies. Due to the large number of model runs, not all of these projection series are reviewed in this report. In the Energy Information Administration (EIA) projection series, for example, only the highest (Series "F" - world oil prices in the range of $20 to $25 per barrel) and the lowest (Series "D" - stable world oil prices at under $16 per barrel, relatively low energy demand and relatively high supply) are presented. Brookhaven makes projections under three scenarios: Basecase (essentially a continuation of current economic and resource conditions); NEP (projections assuming enactment of President Carter's National Energy Program as originally proposed); and High Price III (a "worst case" scenario involving very high oil prices - approaching $60 per barrel, reflecting shortage of petroleum supplies and very high costs for producing synthetic crude oil from coal and oil shale). Foster makes projections under so-called "Free Market" conditions (i.e., domestic crude prices equal to the price of imported oil and natural gas rising to the price of oil on an equal BTU basis), and under "Price Regulation" (i.e., continuation of the price control mechanisms of the Energy Conservation Act of 1975). SRI makes its projections under a

base case and under scenarios involving higher and lower levels of energy demand. SRI points out that changes in the conditions of its base case only move by a relatively short time the introduction of the long-term prices it projects, and do not alter the nature of these prices. The assumptions underlying each of these models are considered in Section III of this paper.

Close examination of the price projections cited in this report indicate the different assumptions regarding not only overall price trends, but also the differences between sectors and fuels. Often the text accompanying the projections gives little explanation for the intersector and interfuel changes.

All prices are given in 1978 dollar values per million BTUs. Prices originally given in 1975 dollars are converted to 1978 figures using the GNP inflator obtained from EIA.

Table 1 is a summary of national average residential energy prices from EIA, Brookhaven, and Foster. EIA's projections are made only for 1985 and 1990. Foster's do not include projections for electricity prices, and Brookhaven's projections for 1990 are not yet complete. Table 2 converts the price projections into annual average percentage changes from the preceding period for which data are available. Figure 1 graphically illustrates the projections in Table 1.

Overall, the highest projections are those by Brookhaven. Both its High Price III and NEP scenarios show 1985 prices above the highest EIA projections for distillate, natural gas, and electricity.

Under Brookhaven's basecase conditions, residential distillate prices rise 3% per year from 1975 to 1985, at 2 1/2% annually from 1985 to 1990, and then at just 1% annually to the year 2000. EIA's high oil price scenario ($19.55 per barrel in 1985 and $24.95 in 1990) shows a 3 1/2% annual increase in residential distillate prices for the 1975-1985 decade, and then a 4% annual increase to 1990. Foster's residential distillate price projections (which were run in 1976) show the lowest increase. In the Foster model, however, prices accelerate after 1990, rising at 3% per year to the end of this century.

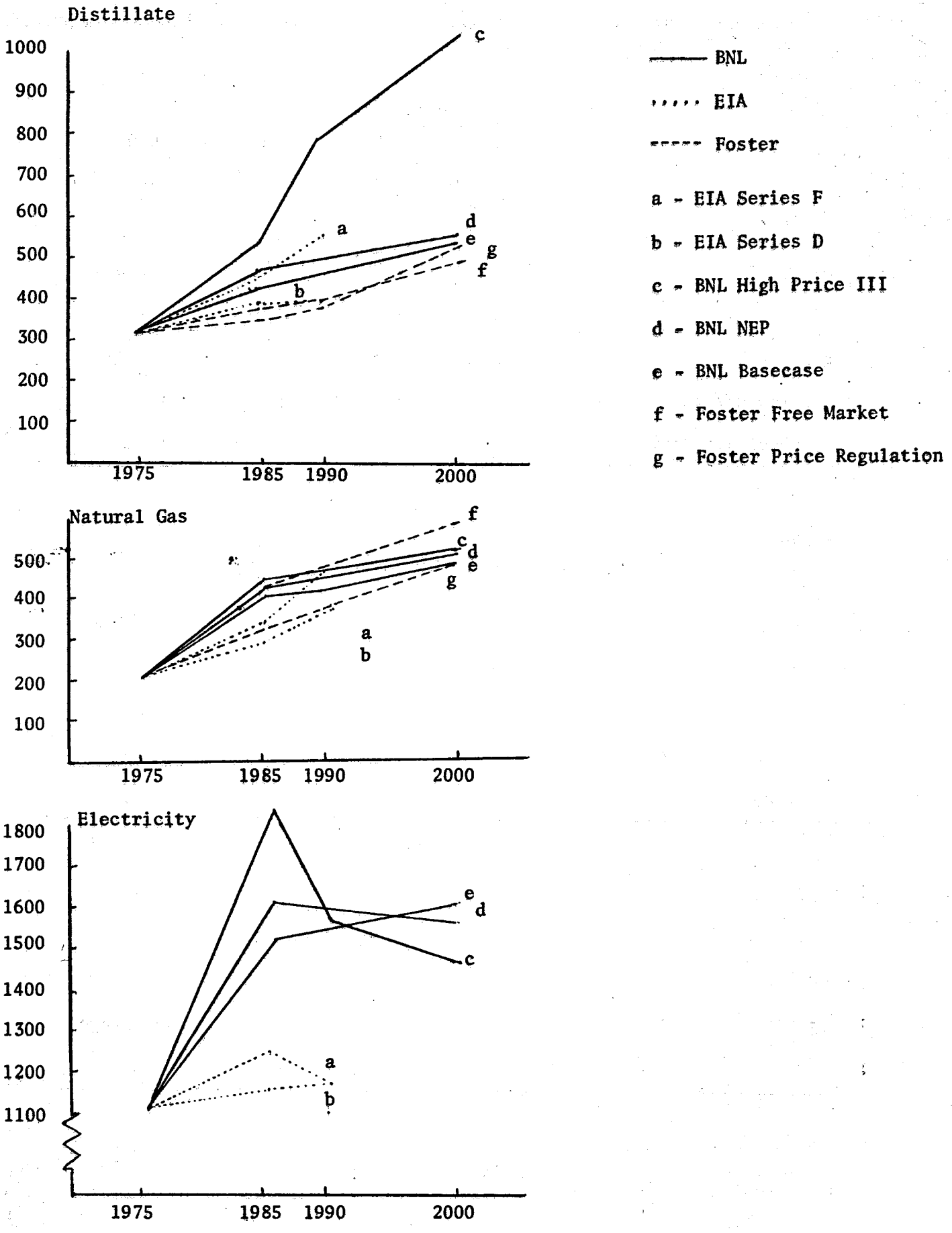
Table 1. Residential Price Projections, ¢/MM BTUs (1978 $)

	1975	1985	1990	2000
Distillate				
EIA - High (Series F)	(318)	449	548	--
Low (Series D)		390	398	--
BNL - High III		545	808	1067
NEP	(318)	467	--	554
Basecase		430	489	547
Foster - Free Market	(318)	373	395	491
Price Regulation		355	382	426
Natural Gas				
EIA - High	(196)	329	449	--
Low		292	363	--
BNL - High III		434	--	514
NEP	(196)	419	--	502
Basecase		405	416	484
Foster - Free Market	(196)	419	446	573
Price Regulation		327	370	481
Electricity				
EIA - High	(1107)	1237	1168	--
Low		1157	1166	--
BNL - High III		1816	1574	1479
NEP	(1107)	1611	--	1572
Basecase		1521	1547	1594

Table 2. Average Annual Percentage Changes in Price (Percentage change from preceding period for which data is given)

	1975	1985	1990	2000
Distillate				
EIA - High	(318)	+ 3½	+ 4	--
Low		+ 2	+<1	--
BNL - High III		+ 5½	+ 8	+ 2 3/4
NEP	(318)	+ 4	--	+ 1 3/4
Base		+ 3	+ 2½	+ 1 1/8
Foster - Free Market	(318)	+ 1½	+ 1 1/8	+ 3
Price Regulation		+ 1 1/8	+ 3/4	+ 3½
Natural Gas				
EIA - High	(196)	+ 5¼	+ 6½	--
Low		+ 4	+ 4½	--
BNL - High III		+ 9	--	+ 1 1/8
NEP	(196)	+ 8	--	+ 1½
Base		+ 7	+ ½	+ 1½
Foster - Free Market	(196)	+ 8	+ 1¼	+ 2½
Price Regulation		+ 5¼	+ 2½	+ 2½
Electricity				
EIA - High	(1107)	+ 1 1/8	No change	--
Low		+ ½	- 1	--
BNL - High III		+ 5	- 3	- 3/4
NEP	(1107)	+ 4	--	No change
Base		+ 3¼	+ ¼	+ ¼

Figure 1. Residential Fuel Price Projections (¢/MM BTUs, 1978$)



Brookhaven's projections show 1985 residential distillate prices ranging from 135% to 170% of 1975 levels in real terms, while year 2000 prices are from 170% to over 335% of 1975 levels. EIA's projections show distillate prices ranging from 123% to 140% of 1975 levels, and from 125% to about 170% in 1990.

Natural gas prices in each of the models and under most runs show the largest increases among the three principal residential fuels. Brookhaven projects large increases up to 1985 and then much more stable prices for the remainder of the century. EIA shows very moderate increases until 1985 and then very rapid rises to 1990. Foster's "Free Market" scenario, like Brookhaven's projections, shows large increases early in the projection period and more stable prices later in the period.

Brookhaven's projections show 1985 natural gas prices to be about 200% of 1975 levels, and about 250% for the year 2000 compared to 1975. Foster's projections for 1990 range from 245% to nearly 300% of 1975 levels. EIA's projections show more moderate increases, ranging from 185% to 230% of 1975 levels by 1990.

Electrical prices in both the EIA and Brookhaven scenarios show actual declines in real price later in the projection period. EIA's high and low projection series show moderate price increases through 1985, and then the two price projections coincide in 1990. Brookhaven shows very rapid increases up to 1985 (a result, apparently, of the still significant role of oil in electric power generation), but then rapid drops after 1985. Despite these declines, electricity prices late in this century remain about three times as high as oil and natural gas prices in the same runs of each model.

Table 3 outlines retail price projections for the commercial sector, and Table 4 shows price projections for the industrial sector. Generally, commercial and industrial prices are projected to remain below those for the residential sector. Under EIA runs, commercial prices are projected to be very close to industrial price levels, while in Brookhaven's and Foster's runs, the commercial prices tend to remain closer to residential price levels.

Table 3. Fuel Price Projections for the Commercial Sector ($/MM BTU's, 1978 $)

	1975	1985	1990	2000
Distillate				
EIA - High	(286)	422	521	
Low		364	371	
BNL - High III		547	808	1067
NEP	(286)	467	--	554
Base		430	489	547
Foster - Free Market	(286)	369	389	488
Price Regulation		348	375	400
Natural Gas				
EIA - High	(154)	315	427	
Low		258	361	
BNL - High III		397	399	483
NEP	(154)	389		471
Base		375	383	454
Foster - Free Market	(154)	385	412	538
Price Regulation		293	336	446
Electricity				
EIA - High	(1090)	1269	1247	--
Low		1186	1205	--
BNL - High III		1778	1917	1448
NEP	(1090)	1578	--	1539
Base		1489	1521	1561

Table 4. Fuel Price Projections for the Industrial Sector (¢/MM BTUs, 1978 $)

	1975	1985	1990	2000
Distillate				
EIA - High	(285)	422	524	--
Low		365	373	--
Foster - Free Market	(285)	312	336	428
Price Regulation		284	320	410
Natural Gas				
EIA - High	(127)	240	316	--
Low		217	246	--
Foster - Free Market	(127)	336	363	489
Price Regulation		244	286	397
Residual				
EIA - High	(226)	357	451	--
Low		302	306	--
Foster - Free Market	(226)	290	311	429
Price Regulation		269	297	397
Electricity				
EIA - High	(603)	915	1071	--
Low		914	940	--

EIA shows commercial and industrial distillate prices rising to between 130% and 180% of 1975 levels by 1990. Natural gas prices for the industrial sector in 1990 are projected to be between 190% and 240% of 1975 levels. Brookhaven's projections show commercial natural gas prices in 1990 at about 260% of 1975 levels and at over 300% by the year 2000. Foster's projections show commercial natural gas prices at 350% of 1975 levels by the end of the century.

In 1975, residential electricity prices were 167% of industrial electricity prices on the average. Under EIA projections this differential is projected to be reduced by 1990 so that residential prices are about 125% of industrial electric prices.

SRI's Long-Term Marginal Price Projections

Stanford Research International's model projects long-term marginal energy prices. These prices differ from the other projections cited in this report in that they do not reflect average or "rolled in" prices or conditions under which producers could charge higher prices (e.g., capture scarcity rents). What they do reflect are the minimum prices required by producers to deliver an additional BTU to the marketplace. They can be viewed as long-term minimum prices. SRI believes that its model is not necessarily representative of near term conditions (it is an equilibrium model, and the near term is not an equilibrium situation). It is believed, however, that the model's predictive ability increases considerably after about 1985, as coal and nuclear energy and synthetic fuels play a larger role.

Table 5 shows the long-term marginal price projections for primary fuels. The relatively stable prices for nuclear fuel and coal result in stable or falling real prices for electricity late in the projection period. In contrast, the marginal prices for oil and gas continue to climb rapidly well past the end of the century.

Conclusions

If the projections of these models are accurate, natural gas users (particularly commercial and industrial users) will face the greatest percentage

Table 5. SRI's Long-Term Marginal Prices of Selected Primary Resources: Base Case (1978 $/MM BTU)

Resource	1985	1990	2000	2022
Nuclear Fuel (U_3O_8)	54	55	55	69
Interior Coal (High sulfur)	80	81	79	77
Great Plains Coal (Low sulfur)	52	52	57	57
Gulf Coast Crude	296	322	391	430
North Slope Crude	254	287	340	354
Crude Import	286	310	363	396
Gulf Coast Gas	284	319	398	413
North Slope Gas	185	161	174	219

increases in real price. It appears, however, that natural gas prices will not exceed those for distillate. Thus, natural gas users would not necessarily represent a greater potential for market penetration by geothermal energy than would users of distillate oil.

The implication of current trends and projected future events, as reflected in the models considered here, is that energy will increase in real value, moderately or greatly, during the remainder of the century. This phenomenon results from a shortage of traditional sources of supply relative to the demand for energy. The American economy is probably responsive enough to avoid the worst of the problems associated with Brookhaven's High Price III scenario, should it occur. The steep rises in oil prices would accelerate the changeover to alternative fuels (provided the rise in oil prices was implemented slowly enough to permit a transition without a breakdown in the economy). On the other hand, the economy is probably not so manipulable as to permit the low demand, high supply, and moderate price conditions of EIA's Series "D" to occur simultaneously. Somewhere in between, the economy is likely to experience significant if not catastrophic dislocations. If geothermal energy is widely perceived to be a secure source of energy, this feature may take on important market value during the period when the dislocations are most severe. However, since electricity offers many of the same advantages, geothermal energy must be price competitive with electric space heating. If the projections cited in this report prove to be accurate, geothermal energy's upper price for market penetration in 1990 would be about 1200 to 1500¢/MM BTUs. It should be noted, however, that electricity prices show considerable regional variation. Section II of this report examines regional energy price projections.

II. REGIONAL ENERGY PRICE PROJECTIONS

Regional price differentials can be relatively large (as much as 15% or 20%) for some fuels, and reflect differences in resource transportation costs, market competitiveness, governmental regulation, and other factors. The influence of specific factors which determine price ratios between regions may change over time, thus introducing even greater uncertainty into regional energy projections relative to national projections. Nevertheless, price projections by region are useful as reminders of the possibly significant differences in prices for specific fuels. This consideration is easily overlooked, if only national average prices are examined.

Brookhaven uses historical price ratios between regional prices and national prices as the basis for projections of future price differences (i.e., the ratios are assumed to hold constant over time).[7]

The EIA model first generates region specific price projections. Its national projections are derived from these regional projections. Foster developed price projections individually for seventeen cities (at least one in each of the nine Census regions). Brookhaven disaggregates its national projections on the basis of historical regional price differentials.

Unfortunately, each of these models uses different regionalization schemes. EIA uses Department of Energy regions of several states. Its regions which cover the areas of interest to this project are the New York and New Jersey region; and the Middle Atlantic region, which includes Pennsylvania, Delaware, Maryland, and Virginia. Brookhaven uses very large portions of the country (Northeast, South, West, etc.). Its regions which are relevant to this project are the Northeast and the South. Foster and SRI use U.S. Census regions. The Census regions which cover the area of interest are the "Middle Atlantic" region, which includes New York, New Jersey, and Pennsylvania; and the "South Atlantic" region, which

includes Delaware, Maryland, Virginia, West Virginia, North and South Carolina, Georgia, and Florida.

For each of these models, the regional prices which apply to the Atlantic Coastal areas of southern New Jersey, the Delmarva Peninsula, and the Virginia, North Carolina tidewater areas are presented in the following tables. Inevitably, considerable distortion occurs, because of the overlaps among the regions, and other problems. For example, even in the relatively small EIA region of New York and New Jersey, the prices given for the region are probably dominated by those in the New York metropolitan area. Prices in southeastern New Jersey may well be closer to those in EIA's "Middle Atlantic" region.

Tables 6, 7, and 8 display the regional retail price projections for each of the three models. Brookhaven provided regional projections for its base case and high price scenario. EIA's national projections are identified by specific assumptions regarding supply, demand, and world oil prices. While the national projections are identified by letters A through F, the regional projections are identified by variations on the three underlying macroeconomic projections. These are CEASPIRIT, an assumption of relatively stable economic growth; CYCLELONG, an assumption of slower growth, higher inflation, and greater cyclical fluctuation than CEASPIRIT; and TRENDLONG, an assumption of long-term relatively steady economic growth. Each macroeconomic projection can be paired with assumptions regarding resource development, energy demand, and prices for imported oil. The EIA regional projections presented here are for three scenarios: "High Resource CEASPIRIT" (the most optimistic, corresponding generally to national projection Series D); "Low Resource CYCLELONG" (less optimistic economic and energy resource development assumptions, but world oil prices remain at about $15.00 per barrel in real terms through 1990); and "High Oil Price TRENDLONG" (which corresponds roughly to national projection Series F). All prices given in this section, as in the others, are in constant (i.e., uninflated) 1978 dollars.

Table 6. EIA Regional Price Projections (¢/MM BTU's, 1978 $)

	Hi-Res CEASPIRIT World Oil = $15.32/brl				Lo-Res CYCLELONG World Oil = $15.32/brl				Hi Oil Price TRENDLONG World Oil 1985=$19.55; 1990=$24.95			
	1985		1990		1985		1990		1985		1990	
	NY/NJ	MidAtl	NY/NJ	MidAtl	NY/NJ	MidAtl	NY/NJ	MidAtl	NY/NJ	MidAtl	NY/NJ	MidAtl
Residential												
Distillate	394	413	408	427	400	418	412	431	453	471	553	571
Natural Gas	395	346	474	398	423	363	484	407	439	381	555	477
Electricity	1599	1397	1666	1404	1576	1386	1634	1379	1713	1453	1809	1443
Commercial												
Distillate	369	374	382	387	374	379	387	391	428	432	527	532
Natural Gas	335	299	413	351	362	317	424	360	378	334	494	430
Electricity	1778	1339	1844	1346	1755	1328	1812	1321	1938	1380	2155	1321
Industrial												
Distillate	367	383	381	397	372	388	385	401	426	441	525	542
Natural Gas	265	257	344	309	293	274	354	317	309	292	425	388
Liquid Gas	374	395	374	395	374	395	374	395	480	500	615	635
Residual	305	317	318	330	310	323	324	337	370	383	459	472
Electricity	955	1105	1022	1112	932	1094	990	1087	882	1073	953	1157

Table 7. BNL Regional Price Projections (¢/MM BTUs, 1978$)

	Base Case						High Price Case					
	1985		1990		2000		1985		1990		2000	
	NE	S	NE	S	NE	S	NE	S	NE	S	NE	S
Residential												
Oil	482	496	498	517	575	591	556	573	825	848	1089	1120
Gas	538	322	557	332	646	385	573	342	576	344	688	411
Electricity	1765	1475	1794	1501	1849	1546	2107	1761	2271	1899	1715	1434
Commercial												
Oil	477	477	494	494	569	563	551	551	816	816	1078	1078
Gas	477	280	540	366	631	338	556	298	560	299	688	411
Electricity	1758	1429	1794	1460	1843	1499	2099	1707	2262	1899	1708	1390

Table 8. Foster Regional Price Projections (¢/MM BTUs, 1978 $)

	Free Market						Price Regulation					
	1985		1990		2000		1985		1990		2000	
	MidAt	SoAt	MidAt	SoAt	MidAt	SoAt	MidAt	SoAt	MidAt	SoAt	MidAt	SoAt
Residential												
Distillate	380	365	403	389	541	514	369	340	399	371	508	479
Natural Gas	405	402	432	429	558	555	313	310	356	352	467	463
Commercial												
Distillate	376	360	398	384	535	511	364	336	395	366	503	474
Natural Gas	418	417	445	444	571	570	326	325	369	368	479	478
Industrial												
Distillate	313	313	343	337	479	463	310	287	340	319	449	428
Residual	298	286	319	306	442	426	282	266	310	296	411	395
Natural Gas	370	362	398	389	523	515	278	267	320	312	431	423

Despite the lack of uniformity in the regionalization schemes of the three models, several patterns are evident in the price variations. Distillate prices are lower in the more northerly regions, while natural gas and electricity prices are lower in the more southerly regions. In each of the models, the regional price differentials are projected to hold more or less constant over the projection period, regardless of the scenario being run.

Oil prices are about 5% higher in the South than in the North. Natural gas prices vary much more by region. Under EIA's projections, they are about 15% to 20% higher in the New York/New Jersey region than in the Middle Atlantic. Under Brookhaven's projections, natural gas prices in the Northeast are about 60% higher than those in the South. Both EIA and Brookhaven show electricity prices being about 20% higher in their more northerly region, compared to the other region. Foster's regional price differences are much smaller than those projected by EIA and Brookhaven. It should be emphasized that it is possible that the degree of regional price variation may largely reflect differences in the areas covered in each regionalization scheme.

Long-Term Regional Marginal Prices

SRI's long-term marginal price projections are provided on the basis of Census regions. Table 9 displays the projections for the Middle Atlantic and South Atlantic regions. Again, it should be noted that marginal prices are not directly comparable to the retail prices projected by the other models.

The regional pattern of marginal prices is very similar to that of the retail price projections, with the exception that marginal prices for distillate are slightly higher in the more northerly region. High BTU gas (natural gas) and electric spaceheating marginal prices are considerably lower in the South Atlantic than in the Middle Atlantic. It is interesting to note that the marginal price

Table 9. SRI Long-Term Marginal Prices by Region (¢/MM BTUs, 1978 $)

	Base Case							
	1985		1990		2000		2022	
	MidAtl	SoAtl	MidAtl	SoAtl	MidAtl	SoAtl	MidAtl	SoAtl
Residential & Commercial								
Distillate	431	428	461	458	524	523	552	550
High BTU Gas	475	438	501	479	532	537	471	464
Electric spaceheat	1159	1111	1158	1110	1135	1018	1038	1006
Industrial								
Distillate	353	350	383	380	446	445	475	472
High BTU Gas	399	356	425	397	457	455	395	380
Low-Sulfur Residual	343	338	366	363	416	421	385	450
Electricity	1043	996	1039	992	1010	995	905	873

differential for high BTU gas diminishes over time. This phenomenon apparently results from the diminishing role of traditional gas fields in the coastal South, and the increasing role projected for liquified natural gas (LNG) imports and synthetic natural gas (SNG) generated from interior coal fields. Natural gas prices are comparatively sensitive to transmission distances and neither SNG nor LNG favors the coastal South over the Middle Atlantic coastal region.

Marginal electricity prices are projected to fall slowly over the projection period, particularly after the turn of the century. This result is due to projected increased use of coal and nuclear fuel (and the declining or steady marginal prices for these inputs) in the generation of electric power. Marginal prices for natural gas also begin to fall late in the period, as LNG and SNG set the price for natural gas. Imports of LNG from countries with large reserves and production of domestic SNG from plentiful coal supplies are assumed to be delivered at steady or falling marginal prices. In contrast, natural gas marginal prices over the next two decades will be greatly influenced by the high marginal cost of additional production from traditional sources of supply, and the scarcity value of the limited production potential of current fields. Marginal distillate oil prices are projected to continue to rise throughout the projection period, though at only ¼% annually after the turn of the century, as synthetic crude oil from coal and oil shale plays a larger role.

III. MODEL ASSUMPTIONS

The specific price projections of the models considered in this report result from the models' representation of important economic relationships and assumptions regarding resource developments and governmental policies. Although each of these models is run under scenarios which vary several important exogenous developments, such as world oil prices or the level of coal development, there are also underlying assumptions which are the same in all of the scenarios. Consideration of these assumptions can be useful in evaluation of the plausibility of the model projections. For example, if a model assumed a rapid expansion of on-line nuclear capacity by 1985, its price projections would seem less realistic. Assumptions regarding production of synthetic liquids and gases (from coal and oil shale) can also be important for indications of possible "security of supply" price premiums which may be attached to the alternative sources of energy, such as geothermal. These considerations are particularly important in the Foster and SRI models, which are run under only a few scenarios.

Energy Information Administration's Projections

Most of the important resource development assumptions in the EIA model are reflected in the various scenarios. Resource availability estimates are taken from the U.S. Geological Survey (USGS). The high energy supply scenarios represent all those resources believed to have at least a 5% chance of "proving out." The low supply scenarios reflect only those resources having a 95% to 100% chance of "proving out." Most of the projection series are run under an assumption that "current practices" will hold, meaning that world oil prices will remain constant in real terms throughout the projection period at $15.32 per barrel, in 1978 dollars. However, EIA notes that "an analysis of future world energy supply and demand reveals that upward pressure on world oil prices could develop during the decade of the 1980's." EIA

scenarios involving rising world oil prices assume that such prices remain constant through 1979, then rise at 5% annually through 1990, when they would be over 60% above current levels in real terms.

Due to the shorter projection period of the EIA model (up to 1990, compared to the year 2000 or beyond for the other models), alternative sources of energy, such as renewable energy resources and production of synthetic crude, are expected to have little influence on price levels.

Brookhaven National Laboratory Energy Price Projections

Brookhaven's basecase projections reflect continuation of status quo conditions, i.e., they represent the energy and economic growth paths that would result if policies and energy conditions evident today remained in force. Among the principal trends assumed are the following:

- domestic natural gas prices are assumed to remain regulated but rates increase over time;
- the real price of imported oil increases at 1% annually;
- U.S. production of oil and gas increases somewhat in response to higher prices, while coal production can be significantly expanded with small price increases.

Among the economic assumptions, one is that productivity will increase more slowly than in the past. Thus, economic growth rates will be lower.

The relative importance of oil and natural gas is projected to drop significantly. In 1977, these fuels combined accounted for three-fourths of U.S. energy consumption. By the year 2000, they are projected to account for about half of total energy consumption. It is assumed that, in the case of natural gas, supply limitations will be reflected in both higher prices and in non-price restrictions on availability.

Coal is projected to increase rapidly in importance. Up to 1990, most of the increase in coal use is accounted for by electric utilities. After 1990, direct use of coal by industry is assumed to account for most of coal's continued growth.

Nuclear energy is assumed to be the major source of projected growth in electrical energy generation. Its share of electrical output is assumed to rise from about 10% in 1977 to nearly 50% by the year 2000.

Electricity use is assumed to grow more rapidly than energy use in general, due largely to the much lower rates of price increase for electricity compared to oil and gas. By the year 2000, electricity is projected to use about 40% of all primary energy input, compared to 30% in 1977.

New technologies, such as geothermal, solar energy, etc., are assumed to come into use during the projection period (up to the year 2000), but play only a very small role in overall energy production.

It is generally assumed that synthetic crude petroleum production from oil shale, coal, and tar sands will ultimately set the price ceiling for world petroleum prices, since the resource base for syncrude could potentially support very large levels of production. Cost estimates for syncrude usually assume that it can be produced for between $15 and $30 per barrel in 1978 dollars.[8] Only limited experience has been gained with actual syncrude plant operation, and so the cost estimates could be very inaccurate. To check the consequences of very expensive syncrude and alternative energy production, Brookhaven ran its High Price III scenario, a "worst case" condition in which world oil prices rise steadily and eventually approach $60 per barrel before synthetics, alternative energy sources, and conservation place a ceiling on the selling price for natural crude oil.

Brookhaven also ran a scenario which worked through the consequences of the implementation of President Carter's National Energy Program as originally proposed.

The Foster Model

The Foster Model uses two interrelated approaches: an empirical analysis of

the factors which are assumed to determine the price of each source of energy, and the judgment of experts regarding both market and nonmarket influences. Thus, Foster's projections are not based on a specific econometric model, but rather are built on key assumptions followed by empirical analysis and expert judgment.

Oil prices in the first half of the forecast period (1975-1990) are assumed to be dominated, not by traditional supply and demand factors, but by OPEC pricing decisions. In Foster's base case (an average of the Free Market and Regulated cases), real world oil prices are assumed to drop about 10% during the 1976-1985 period; to increase about 2% per year from 1985 to 1900; to increase about 3½% from 1990 to 1995; and then to grow at 5% annually through the end of the century.

U.S. oil production is expected to rise from about 8.4 MMBD in 1975 to about 13 MMBD in 1990, and then to rise slowly to about 14 MMBD by 2000. Production of synthetic crude from shale and crude production from tertiary recovery techniques become important about 1990. Projected average U.S. crude prices under free market conditions are (in 1978 $) $14.74 in 1985, $15.90 in 1990, and $22.66 in 2000. The Foster report emphasizes the high degree of uncertainty associated with these forecasts, but stresses the factors working in favor of much higher prices.

Natural gas prices are expected to increase rapidly for the following reasons:

1. Regulation has kept the prices below the market value and replacement costs for the gas;
2. Higher priced supplemental gas (including SNG and LNG) will become a greater portion of total gas supply;
3. If price constraints are removed, gas prices will tend to move to parity with oil prices;
4. Because gas burns clean and hot, it has attributes which have market values which are not currently reflected in market prices.

Estimates of additions to reserves were made under two sets of assumptions, one favoring high production, and another favoring low production of new gas. The high production case leads to an increase in gas supplies of 30% above the low production case. Importation of Canadian natural gas is assumed to fall slightly, and then

remain stable over the forecast period. LNG imports are expected to increase gradually to between 2 and 3 quadBTU by 2000, about equal to the projected level of SNG produced in that year. In 1990, LNG and SNG combined represent about 11% of projected gas supplies.

Nationally, under free market conditions, real natural gas prices are expected to increase over 1975 levels by about 300% for residential users; about 350% for commercial users; and about 385% for industrial users by the year 2000.

Major uncertainties in Foster's gas price projection include the nature of future regulation and the fact that, since gas prices are assumed to rise to parity with oil prices, uncertainties in the oil price forecast carry over to gas prices.

In coal production, Foster assumes a trend away from distinct geographic coal markets for Eastern and Western coal, largely in response to SO_2 regulations. It is further assumed that incremental coal demand will largely be for low sulfur coal, since most of this demand would be coming from large industrial users and power plants which must comply with new source regulations.

Growth in coal supply increases in all regions of the nation from 1974 to 1985, and then the rate of increase slows for the remainder of the century. This slower growth after 1985 results primarily from the assumption regarding increased nuclear power after this time.

Transportation costs are a significant portion of the burner tip price for coal, and will continue to be so over the forecast period. Projected transportation costs are shown in Table 10.

In 1975, average coal prices for electric utilities in the South Atlantic were about $1.18 per million BTUs. Projections for high and low sulfur coal for the South and Mid Atlantic regions are set in Table 11. These price increases are considerably less than those projected for oil and gas.

In 1974, the South Atlantic obtained about 51% of its electricity from coal. About 8% was obtained from nuclear power. In the Mid Atlantic, coal accounted for

Table 10. Foster's Projected Transportation Costs for Coal (¢/ton mile, 1978 $)

	1975	1985	1990	2000
Unit train	1.18	1.77	1.88	2.12
Multiple train	2.36	3.53	3.77	4.24
Slurry pipeline	--	1.07	1.10	1.14
Water carrier	--	.88	.94	1.06

Table 11. Foster's Projections for Coal Prices (¢/MMBTU, 1978$)

		1985	1990	2000
South Atlantic	High Sulfur	147	157	180
	Low Sulfur	174	186	210
Mid Atlantic	High Sulfur	111	119	141
	Low Sulfur	171	181	205

39% of electrical power, while nuclear accounted for 8%. Nationally, coal accounted for 43% and nuclear for 6% of all electrical power generated.

Foster used an optimistic shale production estimate of .3 MMBD by 1985 and assumed that, by 2000, production costs of shale syncrude will have fallen and environmental issues will have been resolved to the point where shale will provide substantial amounts of synthetic crude oil.

Stanford Research International

The most important assumption underlying the SRI model is that long-run energy supplies will be provided from sources which are highly price elastic. Long-run resource prices are assumed to be more sensitive to the cost of production and conversion costs than to the level of demand, because long-run energy supplies are based on abundant coal, oil shale, and uranium.

Generally, domestic oil and natural gas prices are projected to rise relatively steeply, while their market shares fall, reflecting depletion of the resources. Crude imports are assumed to remain relatively constant through 1985 (due to assumed decontrol of domestic oil and resulting short-term production increases). After 1990, imports again begin to grow and continue to increase their market share until the first decade of the next century, when a viable synthetic liquid fuel industry is assumed to be in place.

LNG imports play a role for a time, but it is assumed that synthetic natural gas (SNG) from coal can be produced at lower costs. On the East Coast, however, LNG could still be competitive with SNG, due to transportation cost differences.

Coal production is projected to grow rapidly and, in contrast to oil and gas prices, shows only moderate increases over the forecast period (1985-2022), reflecting the abundance of coal relative to its demand. Unlike oil and gas, the principal uncertainty regarding coal (and nuclear fuels) is not how much is in the ground, but how much it will cost to produce. After the year 2000, an increasing

portion of coal production is devoted to producing synthetic liquids and gases. For example, the synthetics account for about 40% of total coal production on a BTU basis by 2016. Shale syncrude production begins about the year 2000, but remains relatively small (only about 10 quadBTU by 2022).

Nuclear power is assumed to grow rapidly through 1995 and then to slow its rate of growth for the remainder of the projection period.

Electrical power price increases are projected to be modest early in the projection period, and then fall later in the period. However, the continuing high cost of electrical energy compared to other forms of energy will hold down the growth in electrical demand. In the residential sector, however, electricity use for space heating will continue to grow, and it will account for most of the growth in residential energy demand. In summer peaking areas, electrical space heating is viewed as a seasonal load leveler. It is also assumed that electric space heating appeals to building contractors because the capital costs for certain types of electric heating systems are lower than those for other types of heating. The model also assumes a 260¢/MM BTU premium for electricity, reflecting consumer preference compared to natural gas for heating. This premium is based on perceived safety, cleanliness, convenience, and security of supply. Electricity is assumed to be highly competitive in the miscellaneous heating market (e.g., water heating, cooking, and clothes drying), because the low utilization factors favor less capital intensive options.

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Gruy Federal, Inc.	Arlington, VA	J. Renner	1
Gruy Federal, Inc.	Houston, TX	A. Lohse	1
Raytheon Company	Burlington, MA	A. Slater	1
Salisbury Wicomico Economic			
Development Corp.	Salisbury, MD	R. L. Kiley	1
Science Applications, Inc.	LaJolla, CA	J. Wiegand	1
Sperry Vickers	Jackson, MS	D. J. Tearpock	1
Systems Development Corp.	Santa Monica, CA	F. Zimmerman	1
USS Agri-Chemical	Atlanta, GA	R. F. McFarlin	1